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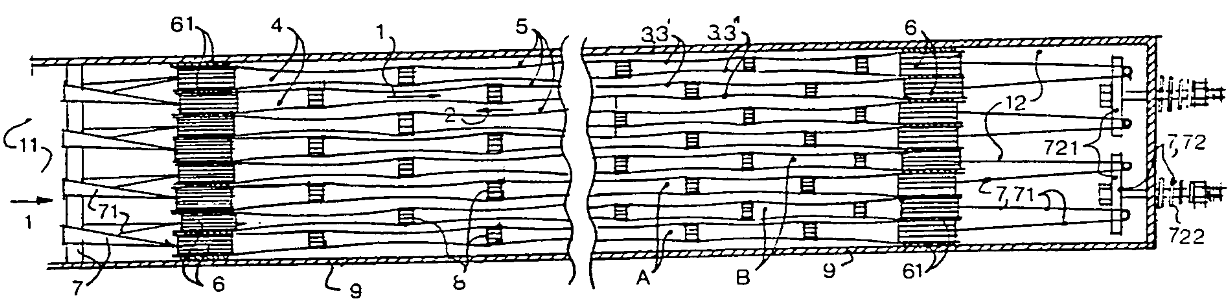

(57) Abstract

A heat exchanger for essentially counterflow heat exchange between two air flows comprises inside a housing (9) essentially parallel partitions (3) of in the air flow direction extended and stretched each with a substantial tension force (P) membranes (3', 3") of high tensile strength, that pairwise (3', 3") essentially gas tight enclose first channels (4) for a warmed, first air flow (1). In alternating second channels (5), surrounding said first channels (4), is propelled a second, cooled air flow (2). The membranes (3', 3") are formed into deflated segments (31) by supporting strips (8) inside said first channels (4), by local static pressure differences (Δp) between said air flows (1, 2) and by said tension force (P).

* See back of page

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THIN FILM GAS HEAT EXCHANGER

The present invention refers to a heat exchanger for essentially counterflow heat exchange between two air flows, comprising inside a housing a number of essentially parallel partitions of flexible membranes forming first channels for a first, warmed air flow and alternating second channels for a second, cooled air flow, further a first inlet and first outlet in said housing for said first air flow and a second inlet and outlet for said second air flow.

A prime use for the invention is heat recovery in domestic and industrial buildigs ventilation system and specifically for heat recovery from very polluted and corrosive exhaust air.

A first purpose with the invention, using thin plastic membranes as heat exchanger surface, is to achieve with simple means full control over flow channel geometry, simplified joining of the separate channel systems to inlets and outlets for the separate air flows and simplified sealing along the rim of the apparatus between the separate air flows.

A second purpose is to provide flow channels for a polluted, moist and corrosive exhaust air flow, cooled in the apparatus, that are smooth, unobstructed by spacing elements, that have a high corrosive resistance and that are exceptionally easy to clean.

A third purpose is to combine reasonable small flow resistance for the air with a well extended channel length needed for high heat exchange efficiency.

A forth purpose is a heat exchanger, that acts as an exceptionally good absorber of fan noise.

Said purposes are met with a heat exchanger further characterized in that it comprises said membranes made of a high tensile plastic film such as polyester film, extended and stretched in the main air flow direction with a substansial tension force, further comprises pairs of said membranes enclosing essentially gas tight said first channels, further comprises the ends of said membranes enclosing and laminated to air penetrable tension plates, preferably of corrugated cardboard, further comprises a strapping device for strapping said tension plates to said housing each with double said tension force,

further comprises said tension plates connected to said first inlet and first outlet and further comprises within said first channels as spacing elements strips of corrugated material, preferably corrugated cardboard, that are positioned essentially at right angle to air flow, are laminated to one of said pair of membranes and that alternate with deflated segments of said membranes, formed by local, positive static pressure differances between said second and first air flow.

Elastic sheets as partitions in a gas heat exchanger are known from SU,A, 1200114. This document shows elastic sheets separated from each other by thin wire spacers, thus forming separate channel systems. This solution is not fitted to a corrosive and dusty exhaust air, since the wire would quickly clug with dust and corrode. Further no provisions are shown to cope with the local, differing pressure gradients on the sheets, due to flow resistance in the channels, or the rim problems of the apparatus concerning well separated inlets and outlets of the separate gas flows. and their connections to the channel systems.

Other documents on thin film heat exchangers show tubular sections in thin film construction, the tubes being formed and stabilized by media pressure and used as spacers as well as heat exchange surface. FR,A, 2289870 and US 4 411 310, figure 15 represent such a principle. These constructions require intriquate welding and the use of a weldable film, which may lack other desired qualities like high tensile strength. They furthermore pose difficult topological problems along the rim of the apparatus in connecting the channel systems to inlets and outlets and efficient sealing.

The invention is in the following described more in detail in relation to the drawings. Figure 1 shows a plan section and figure 2 a longitudinal cross section. Figures 1a and 2a show in plan and cross section an alternative strapping device. In cross sections show figure 3 a package of tension plates, figure 4 flow channels and figure 5 flow channels being cleaned. Figure 6 shows a detailed plan section of flow channels and figure 7 illustrates an example of pressure loss, pressure load

on membranes and spacing of supporting strips in a flow channel.

In referance to figures 1-4 are within a housing 9 arranged a number of essentially parallel partitions 3, forming first channels 4 for a first, warmed air flow 1 and alternating second channels 5 for a counterflow driven second, cooled air flow 2. In the air flow direction the partitions are well extended and comprise in the air flow direction stretched plastic film membranes 3' and 3" of high tensile strength. Each membrane is stretched with a substansial tension force P and the pair of membranes 3',3" enclose essentially gas tight the first channels 4.

The membranes 3',3" are at their ends pairwise laminated to and enclosing a gas penetrable tension plate 6 preferably of corrugated cardboard. In referance to fig. 3 adjacent tension plates are packed to each other and against the housing 9, using suitable intermediate sealing 61.

The tension plates 6 are connected to a first inlet 11 and a first outlet 12 for the first, warmed air flow 1. They are further by a strapping device 7, secured to the housing 9, each affected by a tension force 2P.

The second channels 5 are open in the housing 9 to a second inlet 21 and second outlet 22 for the second air flow 2.

The first channels 4 comprise as spacing elements gas penetrable strips 8 of corrugated material, positioned at intervalls "a" along the channels at essentially right angles to flow direction. The strips alternate with deflated segments 31 of the membranes 3',3", formed by local positive pressure differances Δp between the second 5 and first channels 4. A positive value for Δp is ensured at all points by the coupling of the first outlet 12 to the suction side of a fan for propelling first air flow 1 and the coupling of the second inlet 21 to the pressure side of a fan for the second air flow 2.

The second channels lack spacing elements and has a smooth, unobstructed surface with high corrosive resistance and small dust collecting potential.

Climate inside the first channels 4 for a warmed , first air flow is dry. The strips 8 may therefore like the tension plates 6 be cut out of corrugated cardboard and be laminated to one of the membranes 3' or 3".

As membrane material is preferred a polyester film, type "Melinex" from ICI, in a standard thickness of 75 or 125 for tough conditions. This film is utterly stable in dimension, has high tensile strength and high chemical stability to moisture and corrosive gases. In said thickness heat resistance in the film is negligable. It can be laminated to cardboard with a very strong bond using for instance a vinyleacetateacrylate dispersion.

By folding a rectangular sheet of polyester film and enclosing and laminating a each end a tension plate 6 and along the channel appropriate number of strips 8 an element "A" or "B" is formed, which in the apparatus may be added to any desired flow capacity. The elements may to a small marginal cost be extended in length for increased heat exchange efficiency. Longitudinal open edges of the sheet join by suction in the elements but may further be sealed by a glue bond.

The elements "A" and "B" alternate in the exchanger and differ in that strips in either are displaced half of mentioned interval "a" inrelation to the strips 8 in the other element. In this manner, obvius from figures 1 and 6, the channel 5 aquires a fairly even height and a gently wavy extension with good flow properties.

In order to preserve flow areas, flow velocities and to minimize flow resstance in the channels 4 and 5 in the flow direction the intervals "a" decrease towards the suction end of first channels 4 according to figures 6 and 7 and the following.

The pressure difference Δp between second and first channels will increase from first inlet 11 to first outlet 12. The membrane segments 31 form cylindric surfaces with radius = R from the combination of intervall "a", tension P and pressure differens Δp. Calling depth of deflated segments 31 = h, following applies:

$P = R \cdot \Delta p$ $\qquad 2Rh = a^2/4$ $\qquad a^2 = 8hP / \Delta p$

Depth "h" should be kept constant. It follows:

$$a\sqrt{\Delta p} = \text{constant}$$

An exemple, evaluated in practice, illustrates according to figure 7 a spacing of the strips 8 in accord to this relation. The example, showing corresponding membrane tension, flow resistance, channel dimensions etc. will make the invention more clearly understood. Following applies:

membranes 3',3" length = 1800 mm
" width = 800 mm
number of strips 8 = 13
strip height = 13 mm
height of tension plate 6 = 17 mm
tension force P = 0,075 kp/cm
mean height of channel 4 and 5 = 8 mm
mean air velocities = 3.5 m/s
depth "h" = 3.0 mm
flow resistance in channel 4 = −16 mm wp = p_1
" " 5 = +7 mm wp = p_2
pressure difference Δp = $p_2 - p_1$ as figure 7
intervals "a", calculated, as figure 7
total tension force on each tension plate = 12 kp

Further assuming pressure difference Δp remaining constant, following applies :

$$P \cdot h = \text{constant}$$

Increasing tension P thus reduces depth "h", will increase flow area in channel 4 and correspondingly decrease flow area in channel 5. Thus a doubling of tension P will in above related example change flow area ratio from 1:1 to 1.8:1. Varying the tension P is thus a simple tool to optimize the geometry of the flow channels to varying proportions of mass flows of first and second air.

A strapping device 7 may according to figures 1 and 2 comprise straps 71 anchored to the tension plates 6 and further anchored to the housing directly at one end and indirectly at the other end via an adjustable spring device 72. This spring device may comprise a rectangular plate 721, to which four or eight straps 71 are anchored at the corners. The centre of the plate is pulled by a spring 722. In this manner four or eight tension plates 6 may

equally tensioned by one adjustable spring 722.

An alternate spring device may according to figures 2a and 1a comprise a rubber bag 73, reacting on all said plates 721 and a box 74, anchored to the housing 9. Expanded by pneumatic or hydraulic means the rubber bag will react with the same force on all plates 721 and thus stretch any number of membranes with equal tension P adjustable with the media pressure in the rubber bag.

A mainly horizontal gas flow direction is prefered for drainage out of the bottom 92 of condensate 35 precipitated from the cooled, second air flow 2. From a polluted such flow dust will deposit, specially on moist membranes 3',3". There are cases, where dust clogging is so severe, for instance in pig stables, that known heat exchangers are practically worthless. Even a fatty dust from a pig stable is however readily cleaned from an apparatus according to the invention, as illustrated in figure 5. The air flows are cut off and an upper lid 91 of the housing 9 is removed. Over the package of membranes is sprinkled a suitable detergent 36. Lacking a pressure load Δp, the membranes 3',3" facing second channels 5 will adhere to each other. The detergent will readily wet and by capillary action spread over all membrane surface, soak the dirt and make it loosen. A following water rinsing will readily remove deposits out of bottom 92 and a drain 93.

The apparatus has proven to be an exceptionally good sound absorber. The different, strung segments 31 with separate lengths self oscillate at separate tones and will thus constitute an efficient wide-spectrum noise absorber. With the apparatus connected with first inlet 11 and second outlet 22 to the outside of a building and with first outlet12 and second inlet 21 via air fans to the interior, fan noise to the outside, very often a severe nuisance, is practically totally eliminated.

As appears from the description the invention, using simple means such as corrugated cardboard and thin polyester film, constitutes a useful, versatile tool for heat recovery between air, including very polluted and corrosive exhaust air. The invention solves by simple means the difficult, often neglected topological problems along the rim of the apparatus of well sealed, functional connections between channels and inlets/outlets for the air flows.

1. A heat exchanger for essentally counterflow heat exchange between two air flows, comprising inside a housing (9) a number of essentially parallel partitions (3) of flexible membranes(3',3"), forming first channels (4) for a first, warmed air flow (1) and alternating second channels (5) for a second cooled air flow (2), further a first inlet (11) and first outlet (12) in said housing for said first air flow and a second inlet (21) and outlet (22) for said second air flow characterized in that it comprises said membranes (3",3") made of a high tensil plastic film such as polyester film, extended and streched in the main air flow direction with a substansial tension force (P), further comprises pairs (3',3") of said membranes enclosing essentially gas tight said first channels (4), further comprises the ends of said pair of membranes (3',3") enclosing and laminated to air penetrable tension plates (6), preferably of corrugated cardboard, further comprises a strapping device (7) for strapping said tension plates (6) to said housing (9) each with double said tension force (2P), further comprises said tension plates (6) connected to said first inlet (11) and first outlet (12) and further comprises within said first channels (4) as spacing elements strips (8) of corrugated material, preferably corrugated cardboard, that are positioned essentially at right angle to air flow, are laminated to one of said pair of membranes (3',3") and that alternate with deflated segments (31) of said membranes (3',3"), formed by local positive pressure differences (Δp) between said second (2) and first air flow (1).

2. A heat exchanger according to claim 1 characterized in that it comprises said membranes (3',3") facing said second channels (5) adhering to each other, when said air flows (1,2) are shut off.

3. A heat exchanger according to claim 1-2 c h a r a c t e r i z e d i n that it comprises said strips (8) distributed in any said first channel (4) essentially in the middle between corresponding said strips (8) within surrounding said first channels (4).

4. A heat exchanger according to claims 1-3 c a r a c t e r i z e d i n that it comprises said strips (8) distributed along said first channels (4) with intervals (a) chosen in such a relation ($a \cdot \sqrt{\Delta p}$ = constant) to said pressure difference (Δp) that depth (h) of said segments (31) is kept constant.

5. A heat exchanger according to claims 1 - 4 c h a r a c t e r i z e d i n that it comprises said laminated tension plates (6) of each said end packed against each other and said housing (9) together with intermediate seals (61).

6. A heat exchanger according to claims 1 - 5 c h a r a c t e r i z e d i n that said strapping device (7) comprises straps (71) anchored to each said tension plate (6), said straps further being anchored directly to said housing (9) at one end and indirectly at opposite end via a spring device (72) transmitting to all said tension plates (6) each essentially said double tension force (2P).

7. A heat exchanger according to claims 1 - 6 c h a r a c t e r i z e d i n that said spring device (72) comprises means to vary said tension force (p) and consequently said depth (h) and flow area ratio between said channels (4,5).

8. A heat exchanger according to claims 1 - 7 c h a r a c t e r i z e d i n that said spring device (72) comprises a pneumatically or hydraulically expandable rubber bag (73), reacting on a fixed housing support (74) and flexible strap supports (721).

9. A heat exchanger according to claims 1-8 c h a r a c t e r i z e d i n that it comprises said first air flow (1) being sucked from said first outlet (11) and said second air flow (2) [illegible]

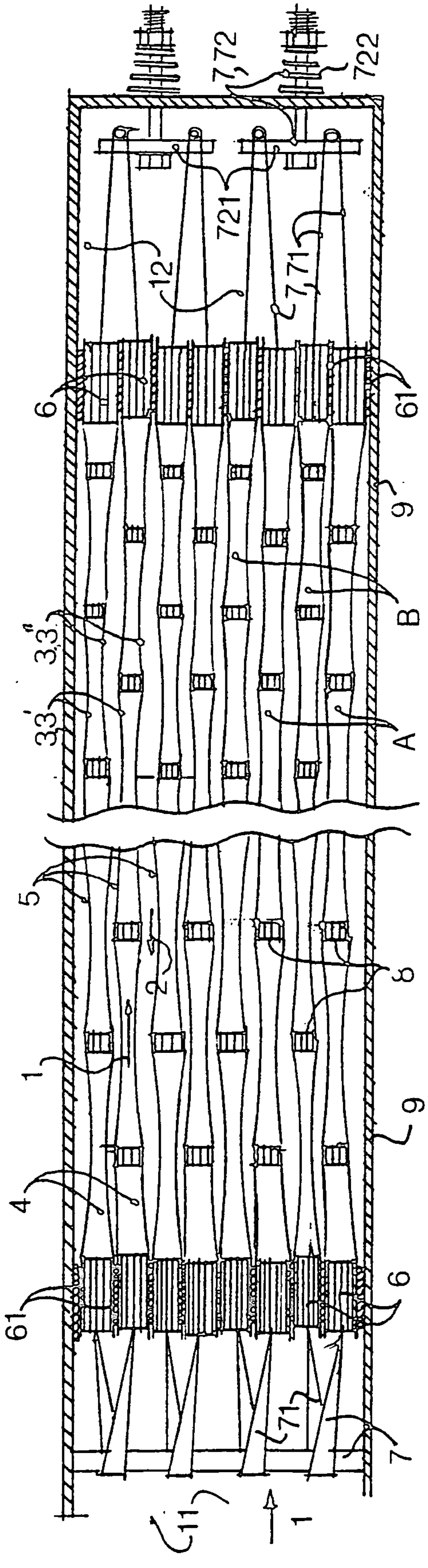


FIGURE 1

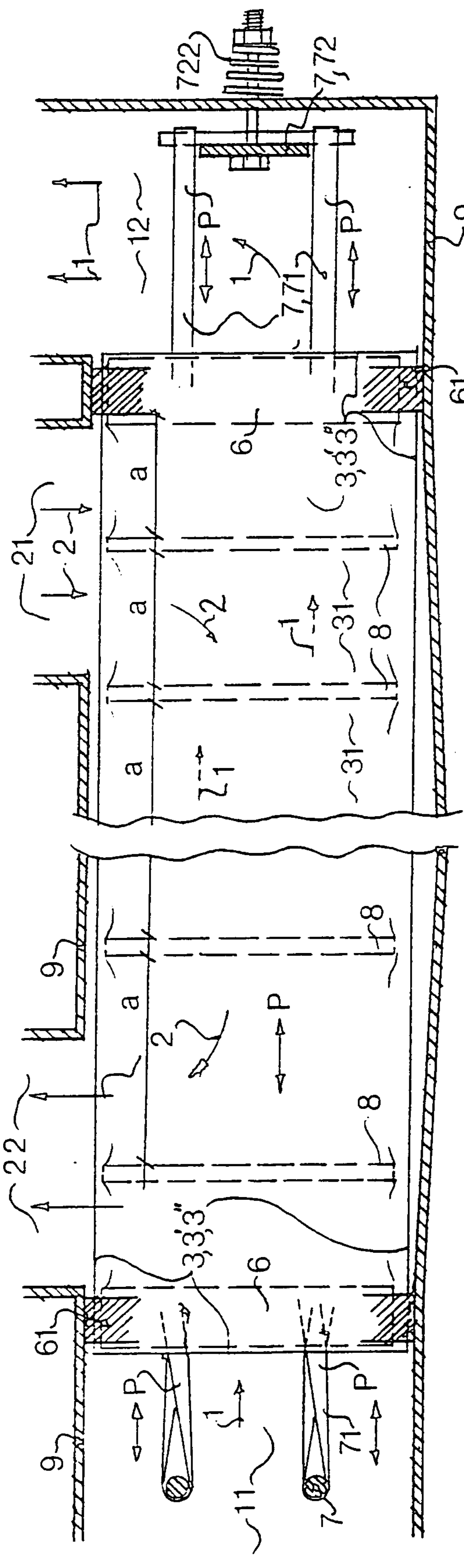


FIGURE 2

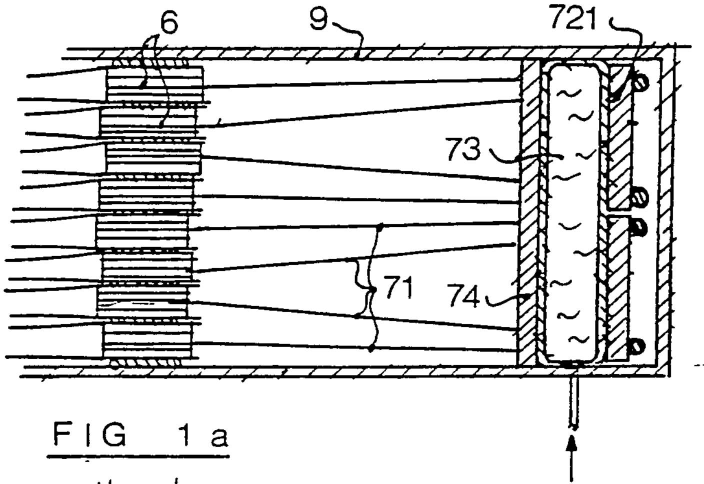


FIG 1a

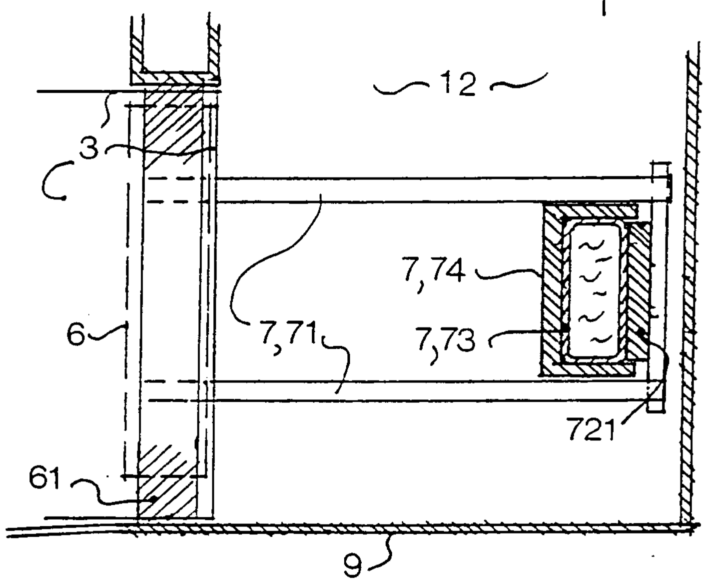


FIG 2a

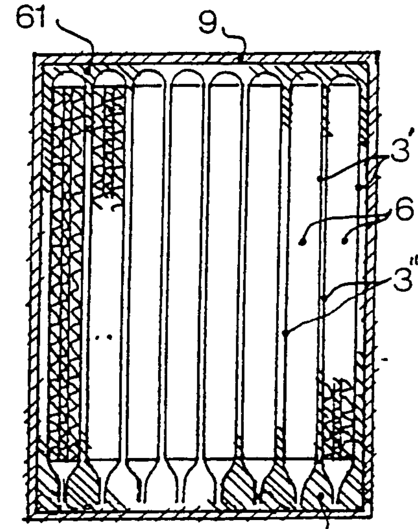


FIG 3

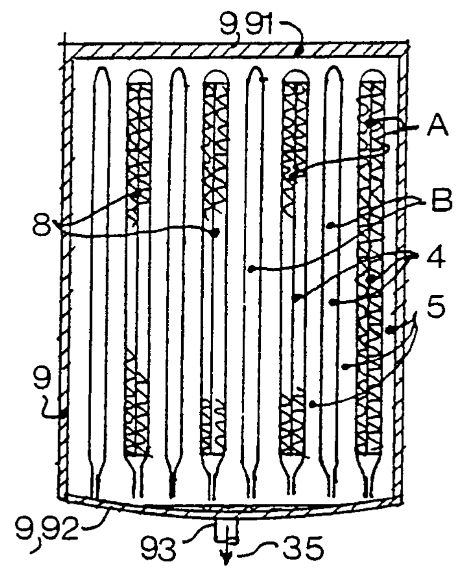


FIG 4

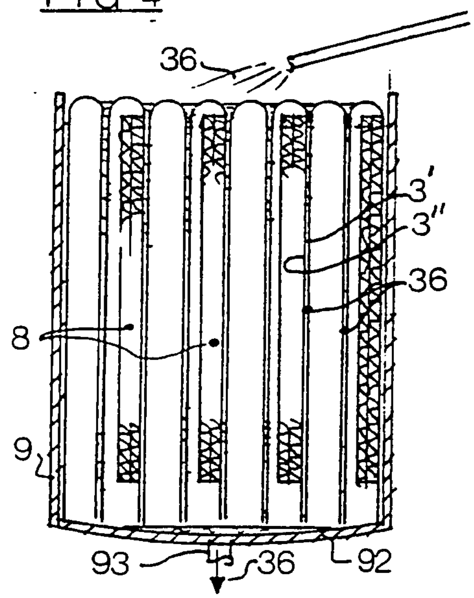
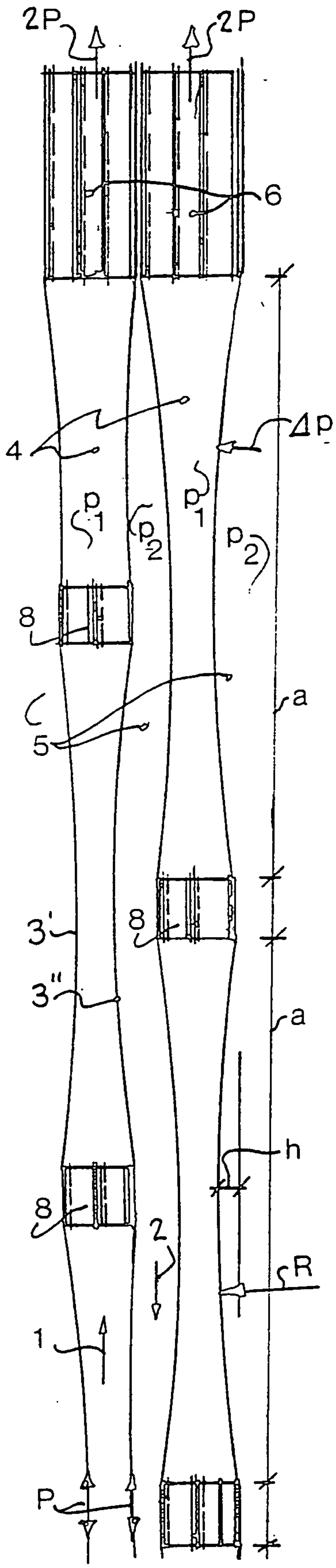
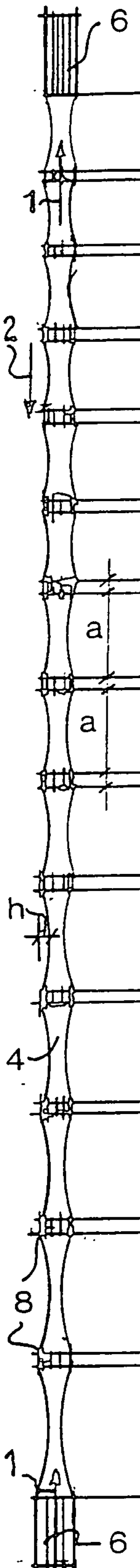


FIG 5



F I G 6

p_1 = −16 mm wp



p_1	p_2	Δp mm wp	a mm
−13,0	5,0	18	90
−12,3	4,7	17	92
−11,5	4,5	16	95
−10,7	4,3	15	98
−9,9	4,1	14	101
−9,2	3,8	13	105
−8,4	3,6	12	109
−7,6	3,4	11	115
−68	32	10	120
−6,1	2,9	9	126
−5,3	2,7	8	134
−4,5	2,5	7	143
−3,7	2,3	6	155
−3,0	2,0	5	170

p_1 = 0 mm wp

F I G 7

INTERNATIONAL SEARCH REPORT

International Application No PCT/SE 90/00584

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all)[6]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC5: F 28 D 9/00

II. FIELDS SEARCHED

Minimum Documentation Searched[7]

Classification System	Classification Symbols
IPC5	F 28 B; F 28 D; F 28 F; F 28 G

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in Fields Searched[8]

SE,DK,FI,NO classes as above

III. DOCUMENTS CONSIDERED TO BE RELEVANT[9]

Category *	Citation of Document,[11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No.[13]
A,E	US, A, 4874042 (BECKER) 17 October 1989, see the whole document --	
A	DE, A1, 3242531 (KÖLLER ET AL) 24 May 1984, see the whole document --	
A	US, A, 4411310 (PERRY ET AL) 25 October 1983, see the whole document --	
A	SE, C, 212919 (C F ROSENBLAD) 16 May 1967, see the whole document --	
A	US, A, 3280906 (C F ROSENBLAD) 25 October 1966, see the whole document --	

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"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
13th November 1990	1990 -12- 1 1
International Searching Authority	**Signature of Authorized Officer**
SWEDISH PATENT OFFICE	Annette Riedel Annette Riedel

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)

Category *	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No
A	SE, B, 379849 (THE A.P.V. CO LTD) 20 October 1975, see the whole document --	
A	FR, A1, 2289870 (MONFRAY) 28 May 1976, see the whole document --	
A	Derwent's abstract, No. 86-195 920/30, SU 1 200 114, publ. week 8630 (CHELY ENERGOTSVETME) --	

ANNEX TO THE INTERNATIONAL SEARCH REPORT
ON INTERNATIONAL PATENT APPLICATION NO.PCT/SE 90/00584

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report.
The members are as contained in the Swedish Patent Office EDP file on 90-09-27
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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US-A- 4874042	89-10-17	NONE	
DE-A1- 3242531	84-05-24	NONE	
US-A- 4411310	83-10-25	NONE	
SE-C- 212919	67-05-16	NONE	
US-A- 3280906	66-10-25	NONE	
SE-B- 379849	75-10-20	DE-A- 2215000	72-10-05
		FR-A-B- 2132183	72-11-17
		GB-A- 1368465	74-09-25
		NL-A- 7204326	72-10-03
FR-A1- 2289870	76-05-28	NONE	